INTEGRATED PEST MANAGEMENT OF POSTHARVEST INSECT PESTS OF DRIED FRUITS AND NUTS

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Processing increases the yearly value of the more than one million harvested tons of California dried fruits and nuts to an estimated $2.4 billion. Insect-related loss costs the dried fruit and nut industry an estimated $96 million each year. Current postharvest insect control measures for the industry depends on fumigation to disinfest large volumes of incoming product during harvest, as well as to control storage infestations. Loss of methyl bromide creates a critical need for economical alternative systems which provide efficacious control and maintain product quality throughout processing, storage, and marketing.

Indianmeal moth, *Plodia interpunctella*, navel orangeworm, *Amyelois transitella*, and raisin moth, *Cadra figulilella*, are among the most serious postharvest pests of dried fruits and nuts in California. Because infestations of navel orangeworm and raisin moth originate in the field and are carried into storage, where adults do not normally reproduce, initial disinfestation of incoming product is sufficient to reduce damage by these pests. In contrast, Indianmeal moth attacks the product after harvest, and is capable of repeated infestation during storage, so that long-term protective treatments provide the most efficient control. To obtain acceptable control throughout the postharvest system, an integrated method, combining initial disinfestation using controlled atmospheres followed by protective treatments of microbial agents, low temperature storage or maintenance levels of controlled atmosphere was proposed.

Materials and Methods:

Walnuts. Commercial raisin bins filled with 500 lbs of 'Hartley' walnuts were used in the tests. For the initial disinfestation treatment, a treatment atmosphere of 0.4% O_2 was produced with a hollow fiber membrane gas separation system. The walnuts were treated at 25°C for 6 days after a purge time of about 2 days. Test insects were 25-day-old navel orangeworm placed individually into drilled walnuts located at the surface of the bins. All nuts were removed after treatment and held for adult emergence.

After the initial low oxygen treatment four bins each were placed under one of the three selected long-term treatments: **IMMGV**, Indianmeal moth granulosis virus (0.0534 g virus preparation/lb nuts), **LT**, low temperature (≤10°C), or **CA**, controlled atmosphere (5% O_2). Another four bins were held as untreated controls. Five mated pairs of Indianmeal moth were introduced into each of the four treatment rooms each week for 11 weeks. Pheromone traps were placed into each treatment room. The traps were monitored each week in the untreated, IMMGV, and LT nuts. The trap in the CA room was examined at the end of the test. The entire test was replicated three times.

Just before each long-term treatment began, a 15 lb walnut sample was removed from the surface of each bin. From each bin sample, 100 nuts were opened and evaluated for damage. Additional subsamples were sent to a commercial laboratory for an industry standard quality evaluation. Similar samples were taken and evaluated 4, 8 and 12 weeks later from the control, IMMGV, and LT nuts; the CA nuts were sampled when the test ended at 13 weeks.

Raisins A single replicate for raisins has been completed. Methods for initial disinfestation were identical to walnut tests, except that late instar raisin moth larvae were used as target insects. Long term treatments were also as above, except that 15 pairs of Indianmeal moths were added each week, the test was continued for 40 weeks, with samples taken every 5 weeks.

Results

Walnuts. In the first two replications, the initial disinfestation treatment was completely effective against navel orangeworm. Technical problems slightly reduced the efficacy of the third replication. During the long-term studies, high numbers of Indianmeal moths were caught in the control room starting six weeks after the beginning of the tests (Fig. 1), with peak numbers between 468-817 per week. Low numbers of moths were caught in the IMMGV room; peak numbers were between 7 and 31 per week. Only one moth was caught in the CA room during replicate 3. No moths were trapped in the LT room.

At the beginning of each replicate, walnut samples from each of the treatment rooms showed mo Indianmeal moth damage and had similar preharvest damage levels (Table 1). Low levels of Indianmeal moth damage and live Indianmeal moth were detected in samples from the control room as early as 4 weeks. Serious Indianmeal moth damage in the control room increased by the 12 week sample to 35%, with an additional 13% of the samples showing minor Indianmeal moth damage and an average of 81 live Indianmeal moth.

Results from the industry standard quality analysis (Table 2) show that at the end of the test, none of the treatments had any negative effect on the quality parameters measured, and were well within acceptable limits. The control samples showed a significant increase in serious damage due to insects and in overall damage. Treatments were similar for all parameters except peroxide levels. These values were significantly lower in LT samples, and remained at the acceptable levels recorded at the beginning of the test.

Raisins. The initial disinfestation proved effective against late instar raisin moth. Pheromone trap results (Fig. 2) show that Indianmeal moth numbers per week in the control room exceeded 50 after 22 weeks, peaking at 140 ten weeks later. The subsequent drop in numbers was believed to be due to activity by *Habrobracon hebetor*, a parasite of pyralid larvae. The difference between damage levels in control and treatment raisins was much less obvious than in walnuts, and is still being analysed. No damage due to Indianmeal moth was found in any of the treatment raisins, while low levels of damage was present in the controls. Raisin quality was maintained throughout most of the test, although high moisture levels found in the LT treatment caused some concern.

Conclusions Our work shows that combining treatments in an integrated approach may offer alternatives to methyl bromide for dried fruits and nuts. However, implementation of this method would involve considerable retrofitting of storage facilities and increased power consumption. Processors may also need to make major changes in product handling. Before the method can be listed as a suitable alternative, an economic analysis of these factors must be done.

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Table 1. Mean (± SD) insects and damage found in walnut samples

Week	Treatment	Live IMM	IMM damage		Total Serious
			Minor	Serious	
0	Control	0	0	0	8.1 ± 1.1
	CA	0	0	0	8.3 ± 1.6
	IMMGV	0	0	0	7.2 ± 1.3
	LT	0	0	0	9.9 ± 1.4
4	Control	0.5 ± 0.4	0.2 ± 0.1	0.8 ± 0.8	9.8 ± 1.2
	IMMGV	0	0	0.1 ± 0.1	7.7 ± 1.4
	LT	0	0	0	7.8 ± 0.8
8	Control	9.2 ± 3.4 a	5.3 ± 1.6 a	4.8 ± 2.3 a	10.8 ± 2.2
	IMMGV	0 b	0 b	0 b	9.7 ± 2.1
	LT	0 b	0 b	0 b	9.9 ± 1.3
12	Control	81.0 ± 13.0 a	12.6 ± 3.2 a	35.1 ± 4.7 a	40.4 ± 5.2 a
	CA	0 b	0 b	0 b	6.2 ± 0.4 b
	IMMGV	0.1 ± 0.1 b	0.2 ± 0.1 b	0.2 ± 0.1 b	9.8 ± 2.1 b
	LT	0 b	0.1 ± 0.1 b	0 b	7.4 ± 0.9 b

Among treatments for each variable and sample date, values followed by a different letter are significantly different (Bonferroni *t* test for mean separation, $P \geq 0.01$).

Table 2. Industry standard laboratory evaluation of walnut quality after 12 weeks of long term treatments. Values are means ± SD

Variable	Control	CA	IMMGV	LT
Moisture Content (%)	3.2 ± 0.03	3.1 ± 0.03	3.1 ± 0.04	3.2 ± 0.05
Water Activity	0.50 ± 0.01	0.45 ± 0.01	0.47 ± 0.02	0.49 ± 0.02
Peroxide Value	0.60 ± 0.09 a	0.61 ± 0.11 a	0.65 ± 0.09 a	0.31 ± 0.26 b
Free Fatty Acids	0.30 ± 0.05	0.25 ± 0.03	0.30 ± 0.02	0.28 ± 0.04
Insect Damage	58.7 ± 4.5 a	5.0 ± 1.0 b	5.2 ± 1.4 b	3.7 ± 1.0 b
Total Damage	62.1 ± 4.4 a	9.9 ± 1.4 b	8.5 ± 2.0 b	9.4 ± 1.8 b

Within rows, values followed by a different letter are significantly different (Bonferroni *t* test for mean separation, $P \geq 0.05$).

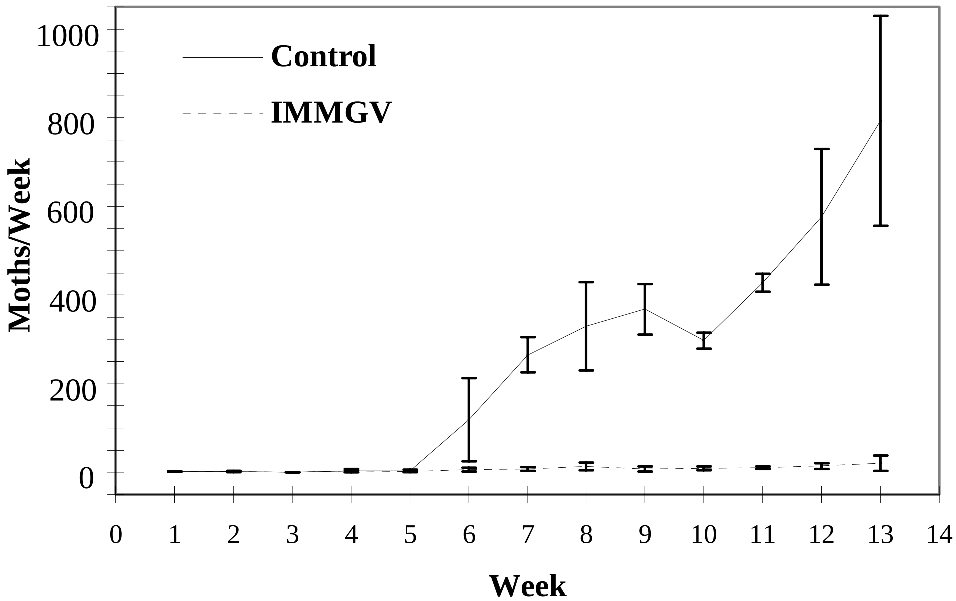

Figure 1. Pheromone traps results for walnut tests (3 replicates)

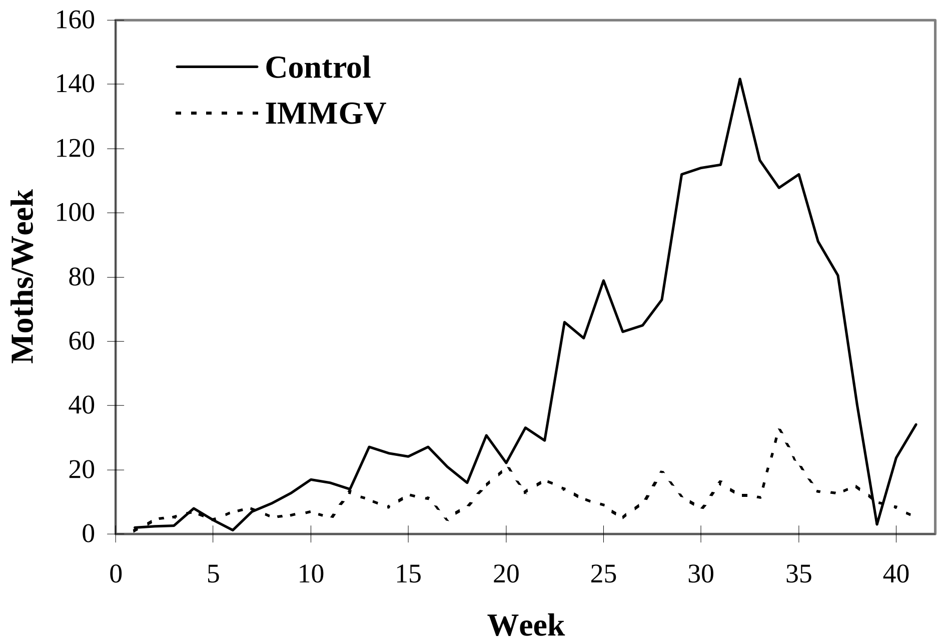

Figure 2. Pheromone trap results for raisin tests (1 replicate)